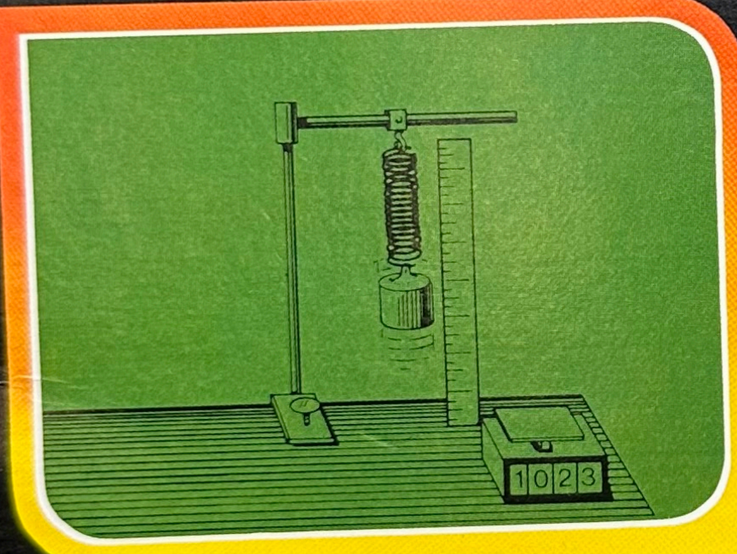
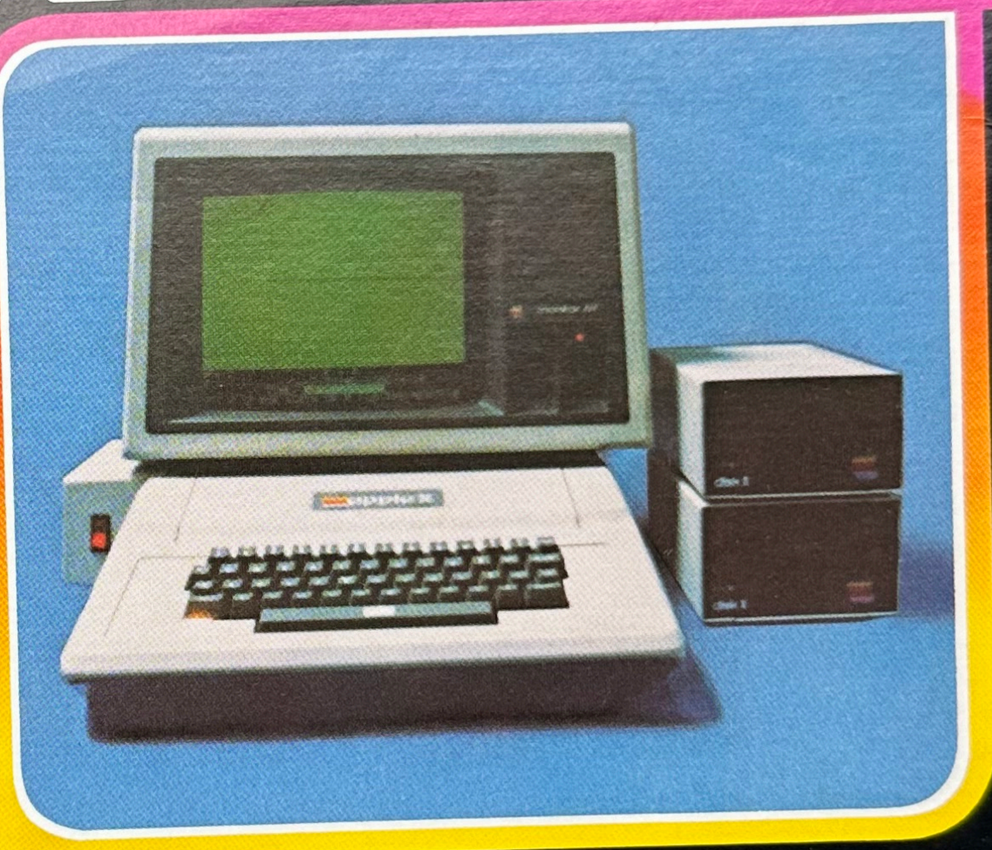
Educational Software for Students in Science and Engineering for the
APPLE II, II+, and IIe

UNPRINTABLE Physics

Sheridan Simon





$$F = ma = -kx - bv$$
$$\frac{d^2x}{dt^2} + \frac{b}{m}\frac{dx}{dt} + \frac{k}{m}x = 0$$
$$x = e^{-(b/2m)t}$$
$$x(x_1 \cos\sqrt{k/m - b^2/4m^2}\,t + x_2 \sin\sqrt{k/m - b^2/4m^2}\,t)$$

32
Simulations, Demonstrations, Examples & Quizzes, as they cannot be done in books

PACKAGE CONTAINS:
1 48K Disk (Apple DOS)
1 User's Manual

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Programs

MATHEMATICAL METHODS

Vectors Shows the components and sums of any vectors you wish
Graph Displays any function in physics and allows evaluation at any point
Least Squares Fit Fits a line to any set of data points you input
* **Definite Integral** Evaluates any function in physics over any finite interval
* **Numeric/Analytic** Compares two solutions of equations of motion graphically

MECHANICS

Trajectory Inquisition Millions of quiz questions to test your knowledge
Expedition to Io The most unfair, brutal trajectory tests of all time
One-D Motion Shows position and speed versus time for nearly any force law
Viscous Motion Settling of particles in a stream under many conditions
Collision Simultaneous display of lab and CM frames with conditions input
Multi-State Rocket Simulates flights of launch vehicles of your own design
Damped Harmonic Demo Displays oscillations with wide choice of inputs
Two-D Harmonic Motion Shows circular, elliptical, and Lissajous motion
Moment of Inertia Calculates this for any set of lines, points, and rings
Kepler's Laws Displays all three laws for your choice of planetary orbits

THERMODYNAMICS

* **Maxwell–Boltzmann Distribution** Molecular speeds at any desired temperature
P-V Graphs Shows change in state of any desired gas for many situations
Thermodynamic Changes Millions of challenging timed quizzes
* **Thermodynamic Cycles** Design your own four-step heat engine
Molecular Motion Shows motion of gas molecules for many input conditions

ELECTROMAGNETISM

Electric Field Field lines of sets of charges at any points you choose
Cathode Ray Tube Displays electron motion for any system you design
Uniform *B* Field Shows motion of electron for any magnetic field conditions
* **LRC Circuits** Simulates voltage across any element of a circuit you design
Electrical Generator Displays voltage output of a generator of your own design

WAVE PHENOMENA

Waves Displays a wave of any desired amplitude, frequency, and phase
Superposition Addition of waves specified by your own inputs
Snell's Law Refraction of light at the interface between any two media
Thin Lens Scale diagram of objects and images for any simple lens

MODERN PHYSICS

Radioactivity Simulated experiments of radioactive dating
Special Relativity Displays time dilation for any relative speed
Hydrogen Spectrum Line produced by any transition plus Doppler shift

*Please note: The educational value of these programs will be enhanced by a knowledge of basic calculus. However, only those programs marked with an asterisk require calculus.

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Interactive
Physics
Simulations
Demonstrations,
Examples & Quizzes
or they
cannot be done in books
MACHALE CONSULTING
1 disk (Apple DOS)
1 user's Manual

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Programs

MATHEMATICAL METHODS

Vectors Shows the components and sums of any vectors you wish.
Graph Displays any function in physics and allows you to explore its behaviour at any point.
Linear Interpol Fits a line to any set of data points you input.
Quad. Interpol Evaluates any function in physics at any point in between two data points you provide.
Roots/Integral Finds the roots and integrates any function in physics over any range you choose.
Numerical/Analytic Compares two solutions of equations of motion graphically.

MECHANICS

Trajectory, Variation Millions of Quiz Questions to test your knowledge
Gravitation More powerful and flexible than the above two programs.
Central Force Solves any problem involving a central force.
Rocket Calculates the trajectory of any rocket with any thrust profile.
Rotational Motion Solves any problem involving rotational motion.
Simultaneous Solves any set of simultaneous equations with up to 20 unknowns.
Matrix Solves any set of linear equations with up to 20 unknowns.

THERMODYNAMICS

Gases Calculates the properties of any gas.
Entropy Calculates the entropy of any system.

ELECTROMAGNETISM

Electrostatics Millions of Quiz Questions to test your knowledge
Circuits Solves any circuit containing resistors, capacitors and inductors.
Magnetism Calculates the magnetic field due to any current distribution.

WAVE PHENOMENA

Waves Displays any wave and its Fourier transform.
Diffraction Calculates the diffraction pattern due to any slit system.

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Electricity and Magnetism
Optics
Modern Physics
Simulated experiments of radioactive dating
Always right! Displays right answer plus Doppler shift
Special Relativity Like produced by any transmen plus speed
Nuclear Reactor Simulation of delayed and prompt neutrons
Nuclear Fusion Simulation of light at the filament of a 25 candlepower bulb
Wave Mechanics Simulated output of a generator of your own design
Wave Interference Requires two of any sound source
Wave Diffraction Requires two of any sound source
Wave Simulator Requires two of any sound source
Electromagnetism Requires two of any sound source
Electromagnetic Induction Requires two of any sound source
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Electromagnetic Induction

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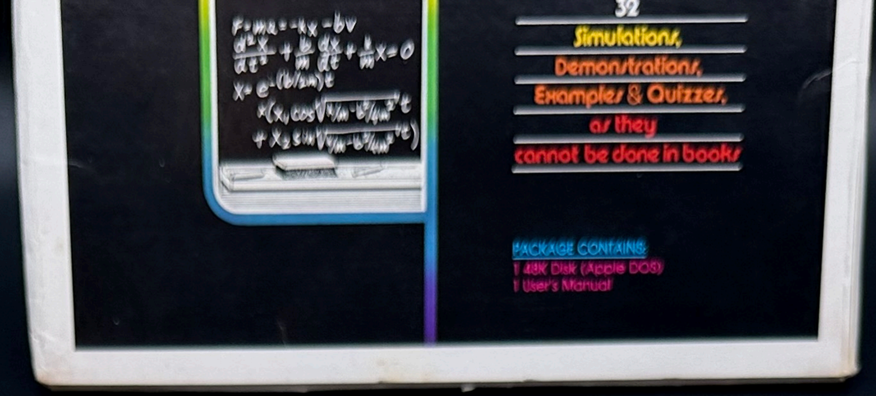

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Introductory
Physics for the
Apple Computer

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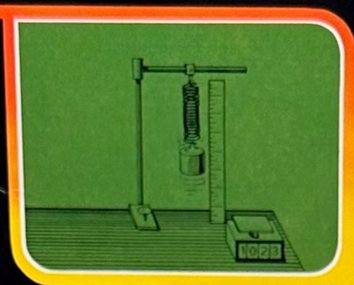

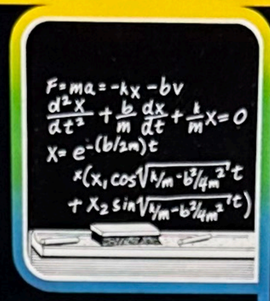

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Protéger
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Jamais
Nie
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Insertar
Insérer avec soin
Sorgfältig Einsetzen
挿入注意

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Jamais
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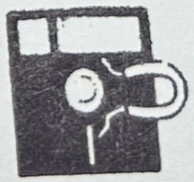
50°F—125°F
R.H. 8%—80%



Never
Nunca
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Physics for the
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P-Hsoftware

PREFACE

These programs are intended to help students learn physics more quickly, more easily, and in greater depth. They are not intended to replace either lectures or textbooks, but to act as a supplement to these more traditional teaching tools. They require no knowledge of programming on the part of either student or instructor. I have tried to design them in such a way that a student will need no more aid in their use and interpretation than is contained in this instruction pamphlet.

I have tried in the programs provided here to take advantage of what I see as a dynamic medium of communication, as opposed to the static medium of textbooks. The programs are of wide variety, but they have one thing in common: every one of them is capable of producing virtually unlimited different responses to student input.

Many of the programs involve graphs or sketches, where the student's inputs have direct, immediate, and visible effect on the output. This differs radically from a textbook presentation, where the number of such diagrams is strictly limited. Conceptually, use of most of these programs has much in common with experimental work. The student can keep all inputs but one constant over several runs of the program, changing that one and noting how it influences the results. Suggestions for utilizing this capability are made in the instructions for individual programs.

The programs can be used to advantage both by students having problems understanding basic concepts and by students seeking more challenging work. Since inputs are in the control of the student, they can be as simple - or as complicated - as the student desires.

While it was not possible for me to include all of the topics found in textbooks on a single disk, I have tried to provide programs that cover most of the major units included in a calculus-based physics survey intended for scientists and engineers. I have tried to place particular emphasis on areas that can be treated to greater advantage by computer than by textbook. Tables of constants, mathematical developments, detailed sketches and photographs, historical commentary, and detailed verbal discussion and analysis have no place here, and are not included.

Although it is somewhat difficult to generalize, I have tried to design a typical program with the idea in mind that an average student should spend one to two hours in mastering its contents. Rather than placing an added burden on the student, the time spent running these programs should mean less time spent reading and rereading texts, seeking the enlightenment provided by faculty and advanced students, and wandering about dormitory halls with a pained expression.

I am grateful to Dr. Paul Doherty of Oakland University, Rochester, Michigan, who very kindly donated his method for inputting functions. This is used in GRAPH, DEFINITE INTEGRAL, and ONE-D MOTION. The meticulous attention to detail of Paul as well as Dr. Larry Kirkpatrick of Montana State University in criticizing the programs has added substantially to their value.

Thermodynamics

M O L E C U L A R M O T I O N

This program allows you to perform simulated experiments on a gas made of non-interacting molecules confined to a square region. One purpose of the program is to allow you to illustrate for yourself an important assumption made in thermodynamics. This assumption is that despite the random motion of individual molecules the net force on the walls containing a large number of molecules is nearly constant.

You get to choose a number of molecules to experiment on (1-60), a side length for their container (20-100), and a Kelvin temperature for them (0-1000). After typing each input, hit RETURN. The container for these molecules is a square. A real gas needs a three-dimensional container, but the results will still make sense. This one is only two-dimensional, but the results will still make some. Just don't apply them to 3-D gases without a little thought.

Once you've input the number of molecules, the size of the box, and the temperature, the computer displays several things. One is a scale model of the molecules in the box. The molecules are started by the computer at random places in the box, moving in random directions at speeds that depend on the temperature.

The computer moves each molecule once in each time step. The distance it moves depends on the temperature. At high temperatures, molecules move a long way during each time step; at low temperatures, the distance covered is comparatively small. Time steps represent very short times as measured in seconds. The air molecules you're breathing are moving at hundreds of meters per second, for comparison with speeds you see on the screen. This means that a measurement of a property like pressure would take many time steps - thousands, at least.

The simulation assumes that the molecules are non-interacting. That is, they move as if they are unaffected by the other molecules - in straight lines, at constant speed, until they hit a wall. You can see this best using a small number of molecules in a big box at low temperature. This assumption is OK so long as the gas being modelled is "dilute." This means there are fairly few molecules in a fairly big container, so the probability of two getting close enough to affect each other is low. Every time a molecule hits a wall, the computer will make a "click," so that you need only to listen to be convinced the collisions are really random.

The molecules' motion doesn't look smooth and isn't intended to. The computer calculates the molecules' positions at short but not infinitesimal time steps. The picture shows this directly.

The computer also prints a running total of collisions of molecules with walls that have taken place. Each tiny hit of a molecule against a wall contributes a tiny amount to the pressure, transferring some momentum to the container wall. In addition, the computer shows how many time steps have elapsed, and the ratio of total collisions to total time steps passed. This last quantity is a crucial one. Since a measurement of pressure takes

a lot of the tiny time steps, what a pressure gauge measures is closely related to the average number of collisions per time step, which is just the ratio referred to above.

The computer also displays a graph of this ratio versus time. You can see fairly easily that during the first few time steps the average number of collisions per time step is pretty random. Over many time steps, however, the average number of collisions per time step gradually settles down to a nearly constant value. This is a good indication that random collisions of molecules with container walls can indeed lead to the pressure being constant, or very close to it.

If you hit A to run again, you can keep your previous value of any input by hitting RETURN instead of retyping it.

There are other uses for this simulation as well. Treat it like an experiment. Keep two of the input quantities constant and vary the third over a number of runs until you understand the results. What happens to the collision rate if the number of molecules is decreased? If the temperature is increased? If the size of the container is increased? Try graphing the ratio of total collisions to total time steps against number of particles, temperature, and side length, in each case keeping the other two constant. Do the results make sense? You might find the program LEAST SQUARES FIT in the Mathematical Methods section useful here. Your text or lecture notes may have the development of the Ideal Gas Law, PV=nRT, from kinetic theory. If so, you can use this simulation to help you develop an analogous formula for two-dimensional ideal gases, which will give you some useful insights.

P-Hsoftware

T H I N L E N S

simulates an experiment with a thin lens (either positive or negative). You can vary both the distance of the object from the lens, its optical axis, the object's size, and the distance of the lens. The focal points of the lens are considered to be at the ends of the optical axis. The object is considered to be a simple arrow with the flat head towards the top of the screen. Measurements are read by the computer and printed on the picture automatically, but the picture artistic skill is very limited).

The object size, image size, focal length, object distance, and image distance are all drawn to the same scale. This can lead to problems when you attempt to experiment with a gigantic object very far from the lens or a tiny one very close. Try to keep your inputs within the same factor of ten of each other. If you don't, nothing awful happens, but the picture may not be of any use to you.

Once you've typed your inputs (hit RETURN after each one), the computer draws a sketch of the situation and prints some information below it. The sketch includes your three inputs along with image size and image distance. Image size is negative if the image is inverted. Image distance is negative if the image is on the same side of the lens as the object. Image size is negative if the image is on the same side of the lens as the object. Image distance tells you how far the image is from the lens, so you can be sure which "nail" in the sketch attention to these numbers so you can be sure which "nail" is the object and which one the image. The object is always upright (of the same the object and to the left of the lens, but sometimes this is true of the image as well.

Below the numerical data is printed

L TO MOVE LEFT, R RIGHT, OR Q TO QUIT.

If you hit Q, you get the usual instructions on what to do next. If you hit L, the object is moved to the left. Its distance from the lens increases by 10% and the sketch and numbers are redone. If you hit R, the object is moved to the right. Its distance from the lens is decreased by 10% and the sketch and numbers redone. This feature will allow you to get some intuition for the behavior of images as the distance between the lens and the object is adjusted.

If you run again by hitting A, you can keep your previous choice for any input by hitting RETURN instead of retyping it.

P-Hsoftware

R A D I O A C T I V I T Y

This program allows you to simulate an experiment involving a radioactive source and a shielding material. The experiment allows you to calculate a property of the atoms of the shielding material referred to as their "cross-section." A material whose atoms have a large cross-section is a good absorber of radioactive emissions. Lead is a good example.

If the number of particles emitted by a radioactive source in some period of time is called N_O, the number N which penetrate an absorber is less than N_O. The relation between N and N_O is

$$N = N_O \exp(- n s x)$$

x is the absorber's thickness in meters. n is the number of atoms per cubic meter of the absorber, called the "number density" of the absorber's atoms. s is the cross-section of the absorber's atoms in square meters, the quantity we wish to determine in this simulation. The relation between N and N_O can be written differently by taking the natural log of both sides:

$$\log N = \log N_O - n s x$$

and this is the form we will use here.

When the program is run, you are shown a sketch which includes a radioactive source (at left) and a detector (at right). You might think of the detector as a Geiger counter. Below the sketch are printed the density D and atomic weight A of the absorber. These can be used to find the number density:

$$n = 6.02 \text{ E}26 \text{ D/A}$$

D and A are chosen randomly by the computer and don't correspond to real materials.

You are first asked to input the absorber thickness, which must be in the range .1 to 1000. The thickness is in microns; 1 micron is 1 E-6 meter. It is best to start with .1 microns for absorber thickness. Once you've typed this, hit RETURN. The absorber is now sketched in between the source and the detector.

N is the number of particles emitted from the radioactive source that reach the counter by penetrating the absorber. The computer counts these for a time of your choice, ranging from 1 to 100 seconds. Radioactive emissions are random, so that if the source is not very strong (not many emissions in an average minute) and the counting time is small you might get a very distorted value for N. If the source happens to emit a lot fewer particles than average or a lot more, it can throw off your calculation of s. This can be helped by using a longer counting time, so the randomness has time to average out. On the other hand, a strong source (lots of emissions in an average minute) may let you use a shorter counting time--

H Y D R O G E N S P E C T R U M

P-Hsoftware

This program allows you to see the spectral lines produced by atoms of hydrogen when their energy changes from a higher to a lower energy state. Such an energy change is called a "transition." The various energies of hydrogen atoms (often called "energy levels") are numbered starting at 1 for the lowest (called the "ground state"), 2 for the next lowest, and so forth. The symbol for the initial n (higher level) and final n, and this input quantity. You input both the initial n (higher level) and final lower level).

The computer plots a picture of a spectrum (not in color, alas) with the spectral line corresponding to the transition from higher n to lower n as a vertical line. Above and below the spectrum (a horizontal band) are small a vertical line. Above and below the spectrum (a horizontal band) are marked as hashmarks corresponding to particular wavelengths, so you can get an idea of the relative position of the spectral lines. The hashmarks are placed at the left end of the spectrum and are placed at start at 1000 Angstroms (= 1 E-10 meters) is a very commonly used unit in spectroscopy. The 1000 Angstroms at the left end of the spectrum and are placed at the right end of the spectrum. The longer hashmarks denote the limits of the visible part of the spectrum (violet), the shorter hashmarks denote the limits of the visible part of the spectrum (red). To the right of the visible spectrum are at 9000 Angstroms (infrared, which your eyes don't detect but the set of "colors" called infrared, which your eyes don't detect but skin does - it's just heat. To the left of the visible spectrum are also invisible, but can be detected ultraviolet wavelengths. They are also invisible, but can be detected by other ways, for example by producing sunburn in lightskinned people.

Below the spectrum are printed your inputs (initial and final n), the Below the spectrum are printed your inputs (initial and final n), the photon emitted (in Angstroms, symbol A), and the energy of the photon. This energy is given in electron volts (eV), a common energy used in atomic physics. 1 eV = 1.60 E-19 joules, but it may be useful to know that photons of visible light have energies between 1.8 eV (deep red) and 3.55 eV (very violet). Infrared photons have ultraviolet more. The energy of the emitted photon is equal to the energy between the energy of the hydrogen atom in its initial state in its final state.

After the numerical output is printed

MORE LINES (M), DOPPLER SHIFT (D), OR QUIT (Q):

If you hit M (no RETURN needed) you get the usual instructions on how to proceed. If you hit M (no RETURN needed), the program lets you input another initial n and final n while keeping the spectrum with the line already displayed. You can repeat this as many times as you wish, adding more and more lines to the spectrum. In this way you can see the set of spectral lines produced by atoms falling to final energy state n=1 from initial

states n=2, 3, 4, ... This set of lines is called the Lyman series. The set produced by hydrogen atoms falling to the final energy state n=2 from initial states n=3, 4, 5, ... is called the Balmer series, and is of great importance in astronomy and astrophysics. After adding any new line or lines to the first one drawn, you lose the option of Doppler shifting your first line. The computer prints

MORE LINES (M) OR QUIT (Q):

under the numerical data on the last line you added to the spectrum.

If you hit D (no RETURN needed) after inputting the initial n and final n for your first line, you see printed

IS SOURCE MOVING TOWARD (-) OR AWAY (+)
FROM US:

A source of a spectral line here might be thought of as a sample of hydrogen. If it is moving towards you a line in its spectrum won't appear at the usual wavelength. It will be at a smaller wavelength. If the hydrogen is moving away from you, the line appears at a larger wavelength than if the hydrogen were standing still relative to you, an effect often called the "red shift."

Once you hit + or - (no RETURN needed) the computer asks for the speed of the source in meters per second. Type this, then hit RETURN. The computer now draws a second spectrum below the first with the line in its Doppler shifted position. Below the two spectra is printed the wavelength of the Doppler shifted line, the unshifted wavelength (observed if the speed of the source is zero relative to you), and the speed you input. The bigger the speed, the larger the shift. You won't see much of a change unless the speed is several million meters per second.

Measurements of wavelengths of spectral lines from objects in space allow calculation of Doppler shifts from wavelengths observed from sources at rest. This in turn allows calculation of the object's speed. Calculations like this have revealed the incredible fact that the entire universe seems to be expanding.

Sometimes your input values of n or strong Doppler shifts produce lines at wavelengths shorter or longer than can be displayed on the spectrum drawn. In this case, the wavelength printed below the spectrum is printed black-on-white instead of white-on-black, and no line will appear on the spectrum.

T H E E N D